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The lesser mottled grasshopper, *Stenobothrus stigmaticus*: lessons from habitat management at its only site in the British Isles

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Abstract

The lesser mottled grasshopper, *Stenobothrus stigmaticus*, occurs at a single site in the British Isles. This paper describes the history of site protection and management over 30 years including the introduction of conservation grazing management. Successes have been limited, but this has been due largely to issues around recreational access and stakeholder engagement rather than lack of ecological understanding. Despite severe challenges, sufficient experience has been gained to be confident that grazing by sheep can assist in re-establishing the grasshopper over areas of a protected site from which it is now absent or present in only scattered colonies. The grasshopper requires a short, open grassland and pockets of such vegetation occur naturally because of rabbit-grazing and thin, nutrient poor, free-draining soils around rocky outcrops. These small areas have proved to be critical to the species persistence and provide a nucleus from which spread can occur. Grazing management has involved complex negotiations with multiple stakeholders, including landowners, their agents, the landowners' tenants, and the tenants' graziers. Public access, cases of dogs worrying grazing livestock, and objections over the introduction of fencing in a once open landscape have made negotiations more difficult. Future success requires that these issues be addressed. Observations on a golf course within the site, with a remnant population of the grasshopper, suggest that winter-cutting of grassland may be a useful supplement to grazing management while such difficulties remain.

Key words

dogs, golf course, grazing, heathland, Isle of Man, mowing, protected area, recreation pressure, sheep worrying

Introduction

The lesser mottled grasshopper *Stenobothrus stigmaticus* (Rambur) (Orthoptera: Acrididae: Gomphocerinae) is widespread in western, central and eastern Europe, but is often locally uncommon and declining because of habitat loss and abandonment of grazing on its favored agriculturally marginal habitats (Detzel 1998, Benton 2012). In common with many threatened species, there is a body of evidence describing the species distribution, but limited autecological information, and even less practical knowledge on how its habitat should be managed. In this paper, we review the species habitat requirements with a focus on central and north-west Europe, and provide a detailed case study of the successes and failures of conservation grazing management at the species only known site in the British Isles (Ragge 1965, Cherrill 1994, Benton 2012). We aim to provide an informed basis for future conservation management of the species here and elsewhere in north-west Europe.

Habitat associations

Throughout its range, *S. stigmaticus* is restricted to semi-natural habitats which have not been subjected to agricultural improvement through re-seeding or addition of artificial fertilizers (van Wingerden et al. 1992, Detzel 1998). Consistent features of sites occupied by *S. stigmaticus* are that they are warm and dry, with nutrient poor, free-draining soils supporting short open vegetation (van Wingerden and Dimmers 1993, Detzel 1998). The geology appears unimportant since the species occurs on sites with acidic and calcareous soils.

The habitat of *S. stigmaticus* has been described variously as heath and dry grassland (Harz 1975, Detzel 1998, Behrens and Fartmann 2004), chalk grassland (Hoffmans et al. 1989), moorland and clearings in planted woods (Holst 1986), warm, dry places with very short grass (Bellman 1988, Johannesen et al.1999), *Deschampsia flexuosa* grasslands (van Wingerden et al. 1991a), inland sand dunes (Detzel 1998), *Carex arenaria* river dunes (van Wingerden and Dimmers 1993), dry acidic *Nardus* pastures with a mosaic of dwarf scrub heath, and dry base-rich *Bromopsis* grasslands (Detzel 1998).

The habitat of *S. stigmaticus* on the Isle of Man accords with that reported elsewhere in Europe. The population occurs at greatest densities in areas with short grassland, heath, and well-drained maritime grassland on rocky cliff tops (Cherrill 1994, Cherrill and Selman 2002) (Figs 1, 2). Highest densities occur in areas of short grass-dominated turf (less than 15 cm tall). Inter-specific comparison of species' microhabitat selection is useful to place the requirements of *S. stigmaticus* in context. On the Isle of Man, *S. stigmaticus* co-occurs with *Myrmeleotettix maculatus* (Thunberg) (Orthoptera: Acrididae: Gomphocerinae) in areas with short turf (< 5cm) and bare ground, but also extends into taller sparsely tus-

Fig. 1. Langness Peninsula in July 2006: **A.** and **B.** Short grassland supporting *S. stigmaticus*, *M. maculatus* and *C. brunneus* around rocky outcrops above the shore (with AJC taking notes); **C.** short grassy heath supporting *S. stigmaticus* near the mid-line of the peninsula; **D.** tall grassland and gorse near the mid-line of the peninsula with scarce *S. stigmaticus* restricted to short grass close to rocks and *C. brunneus* throughout; **E.** a path with *S. stigmaticus* occurring immediately adjacent and *C. brunneus* extending into the taller grassland beyond; and **F.** a patch of semi-rough (with RGS inspecting a grasshopper) and a grassy mound supporting *S. stigmaticus* and *C. brunneus* within the golf course.

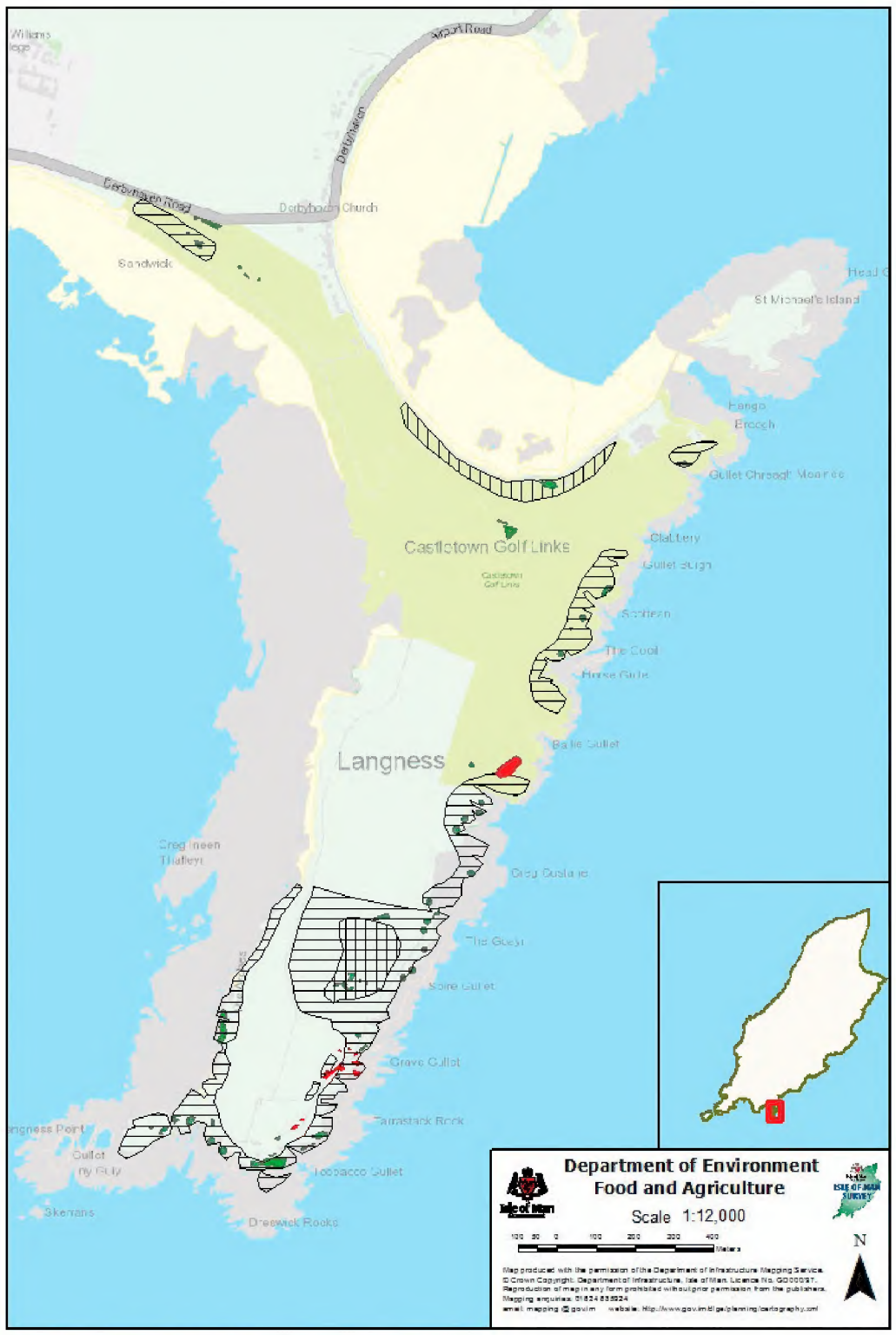

Fig. 2. Aerial photograph of Langness, showing the area covered by the golf course (light green), the distribution of *S. stigmaticus* in August 1964 (vertical hatching), 1990 (horizontal hatching), and sites occupied from 2002 in the absence of grazing (dark green) and sites occupied from 2002 where grazing had been re-introduced (red) (based on mapping by Mr. J. F. Burton reported in RPS Clouston (1990), Cherrill (1990, 1994) and subsequent observations by the authors).

socky vegetation (up to approximately 15 cm) occupied by *Chorthippus brunneus* (Thunberg) (Orthoptera: Acrididae: Gomphocerinae) from which *M. maculatus* is absent. Moreover, while *M. maculatus* is strictly associated with patches of bare ground, this is not the case for *S. stigmaticus*, and of the three species, only *C. brunneus* occurs in the tallest grassland (>15cm). Thus, compared with the two species with which it coexists, *S. stigmaticus* typically occurs in grass of short to intermediate height, and is often but not exclusively associated with patches of bare ground. A similar situation is reported by Behrens and Fartmann (2004) in Germany. The habitat requirements of *S. stigmaticus* appear to be linked to the warm, dry conditions needed for egg development, feeding on fine-bladed grasses such as *Festuca rubra* L., and thermoregulation of nymphs and adults (van Wingerden et al. 1991b, Isern-Vallverdu et al. 1995, van Wingerden and Hereen 1998, Länder 2000).

Livestock grazing is important in maintaining habitat for *S. stigmaticus*, although at some sites grazing by wild deer and rabbits appears to be sufficient (van Wingerden and Dimmers 1993, Detzel 1998). Sheep grazing is a common form of management in many areas with *S. stigmaticus* and extensive sheep grazing is therefore a recommended form of vegetation management for this species in Germany (NLWKN 2011), although cattle, horses and goats can also produce a suitable sward (van Wingerden et al. 1991a, Jauregui et al. 2008, Elligsen et al. 2010, Werkgroep Saltabel 2017).

The lesser mottled grasshopper on the Isle of Man

The population of *S. stigmaticus* on the Langness Peninsula represents the species' northernmost outpost in Europe and is the species' only known location in the British Isles (Ragge 1963, Benton 2012). The population provides an example of a thermophilous species at the northern edge of its distribution. Such populations are often susceptible to extinction through degradation of habitat quality (Benton 2012).

The Langness Peninsula is approximately 2.5km long and 0.5km wide, and is formed from a rocky islet connected to the main island by a sand tombolo (Fig. 2). The landward section of the peninsula is dominated by a golf course laid out in the early 1900s and redesigned in the late 1940s. The original vegetation is thought to have been a maritime grassy heath (Radcliffe and Garrad 1990). Semi-natural grassland and dwarf shrubs still occur, particularly along rocky outcrops above the eastern shoreline, and dune-like vegetation occurs on blown sand in limited areas on the western shore and within the golf course. The golf course is thought to have been grazed by sheep over winter in the 1940s and 50s but has since been ungrazed. The golf course is currently managed by mowing. The semi-roughs and roughs include small areas of remnant or recreated semi-natural vegetation.

The southern (seaward) end of the peninsula has a rocky shoreline on all aspects. Maritime grassland, with scattered heath, occurs near the shore. Inland is unimproved grassland, heathland around scattered rock outcrops, and a ploughed field (which has been cultivated in recent years for cereals grown under organic principles and to promote rare arable weeds after many years of abandonment). Until 1987 the southern end of the peninsula was grazed by sheep and cattle on an extensive basis (Selman 2012).

The grasshopper was present at a small number of scattered locations within the golf course in 1964 and this has remained the case, but since discovery its main distribution has always been in the less intensively managed southern part of the peninsula (Burton 1965, RPS Clouston 1990, Cherrill 1994) (Fig. 2). In the 1980s, attention was focused on the grasshopper as a result of a plan to extend the golf course into the southern part of the peninsula. This culminated in a Public Inquiry, rejection of the planning application and ultimately contributed to the decision to designate Langness Peninsula as the Langness, Sandwick and Derbyhaven Area of Special Scientific Interest (ASSI) under the Wildlife Act (1990) in 2000. The grasshopper, *S. stigmaticus*, had previously been listed in Schedule 5 of the Act, prohibiting intentional (and more recently, reckless) damage to the species or its habitat. These developments facilitated the reintroduction of grazing to the southern end of the peninsula in 2003 as part of a Management Agreement between the owner and the Department of Agriculture, Fisheries and Forestry (DAFF) (which in 2010 was absorbed into the new Department of Environment, Food and Agriculture (DEFA)).

The following sections focus primarily on grazing management in the southern half of the peninsula, although lessons arising from mowing within the golf course are summarized. The article is based mainly on unpublished reports (Cherrill 1990,

Cherrill and Selman 2002, 2006, Selman 2009, 2012, 2014, 2017), material recorded in the site management files and based on ongoing discussions with stakeholders variously involved with the site. Recording of the species distribution and abundance was semi-quantitative and undertaken by walk surveys in warm, sunny weather when nymphs and adults were active. Photographs taken in July 2006 are included to illustrate key habitat features (Fig. 1).

Fifteen years without grazing: 1987–2002.—Following limited survey work in the early 1960s (Burton 1965), there were no further searches for *S. stigmaticus* at Langness until the Public Inquiry stimulated an investigation in 1990 (Cherrill 1990, 1994) (Fig. 2). This revealed that *S. stigmaticus* was abundant in maritime heath and grassland along the rocky shores in both the north and south halves of the peninsula (Fig. 1A, B). It was also abundant on a block of heath and around rocky outcrops in areas of the unimproved grassland in the center of the southern part of the peninsula (Fig. 1C). Twelve years later, and after 15 years without livestock grazing, a new survey confirmed the presence of *S. stigmaticus* in the same general areas identified in 1990. The grasshopper had, however, become less abundant and its distribution was more fragmented than that described in 1990 (Cherrill and Selman 2002) (Fig. 2). The co-occurring species, *M. maculatus*, had also become less common, supporting observations of a reduction in area of the short turf required by both species. Whereas in 1990, *S. stigmaticus* occurred in almost an unbroken ribbon in grassy heath above rocky shores, by the early 2000s small colonies were isolated on south-facing slopes, particularly at the heads of rocky gullies leading down to the sea where wind exposure, thin soils on steep slopes, salt spray and rabbit grazing limited grass growth (Cherrill and Selman 2002, 2006) (Fig. 2). These areas have been critical for the persistence of *S. stigmaticus* in the absence of livestock grazing.

Away from the shore, *S. stigmaticus* appeared to be even more dependent on localized rabbit grazing and the presence of thin, free-draining soils around rock outcrops. The species had declined more sharply than seen near the shore, and was restricted to patches of short grassland associated with rock outcrops (Fig. 1C) and along the edges of heavily trampled footpaths (Fig. 1E). Grassland, between rock outcrops and on deeper soils and with little grazing by rabbits or trampling by walkers, was knee-high with a thick layer of dead litter (Fig. 1D), whereas it had been only ankle-high with patches of bare ground in 1990. Paths crossing gorse heath in the center of the peninsula had also become impassable to walkers by the early 2000s. Many such areas occupied by *S. stigmaticus* in 1990 did not support the species in 2002 because of the taller vegetation and accumulation of leaf litter.

Grazing reintroduced under a Management Agreement: 2001–2012.—By 2000, and the designation of the ASSI, it was already apparent that a re-introduction of grazing was desirable. DAFF established a Management Agreement with the owners of land in the south of the peninsula to run from 2001. A key aim was to bring habitat back to suitable condition for *S. stigmaticus*. This was facilitated with an annual payment to compensate for the challenges of conservation grazing and payment of the costs of fencing.

The fencing was put up in 2002/3, but there was outrage reported in local newspapers against the aesthetic impact, and because fences blocked the routes of some of the paths used by local people for recreation, though access was retained across the area (except the arable field) (Cannan et al. 2008). Access had been allowed previously by permission of the landowners and had become expected by local residents, though the only designated rights of way were along the highways. The matter came to a head in 2005 when the south-western point was closed to public access by the landowners, utilizing new fences, in an effort to protect their privacy in adjacent buildings. A campaign group was set up and demanded the designation of rights of way, including access across this area. This led to negotiation via a political delegation (Cannan et al. 2008), and when that failed, another Public Inquiry. A legal determination in the High Court resulted in the designation of a network of footpaths in 2012. Throughout this period, the grazing management of the land was hampered because the issues of access, grazing and fencing became entangled. It became particularly difficult to achieve consistent grazing due to instances of walkers' dogs worrying the sheep, which dissuaded the tenant from stocking the land. Another unintended consequence of fencing was that a few paths, previously kept open by trampling, were cut off by the fences and rapidly became overgrown. The mid-lines of footpaths were never suitable for *S. stigmaticus*, but where short trampled turf graded into taller vegetation, suitable habitat resulted (Fig. 1E).

There was sheep grazing from 2002 to 2004, but then a change of land ownership necessitated renegotiation of the Management Agreement and sheep worrying issues started in 2005, which made this more challenging and added to the access discussions. As a result, grazing was not re-established until 2007, when a Management Agreement was made with the new owners specifying stocking rates equivalent to approximately 4 to 5 sheep per ha for a minimum of eight months per year. The agreement permitted the use of cattle as an alternative, but it was sheep grazing that was taken up. Grazing by sheep then continued until 2009, but because of the dog attacks the full eight-month prescription was achieved in only one of those three years. Between 2005 and 2009, around a dozen lambs and ewes were killed outright, chased over cliff edges to their deaths, or had to be euthanized after being mauled by dogs or injured on the rocks.

Despite these problems, grazing had some positive impacts on the grassland structure. Surveys in 2006 and 2009, showed the extension of *S. stigmaticus* from remnant colonies at the heads of gullies above the shore, into grassland towards the center of the peninsula where the species had been recorded in 1990 but not in 2002. In 2006, this was evident in one area even though the area had been ungrazed for the two years previous, but having received sheep grazing for two years before (Selman 2009).

In limited areas, grazing created a structure that allowed the spread of *S. stigmaticus* from isolated remnant colonies, but this never reached the level necessary to have an impact on the distribution of *S. stigmaticus* across the whole site. Fundamentally, there were too few sheep for too short a period each year.

With continued problems around public access and dog attacks, there was again no grazing in 2010 and only brief grazing by a couple of horses in 2011, with little effect on the habitat. From the start of the dog issues there had been discussions regarding the need for livestock that would accept rough herbage, be robust against dogs, yet be safe around walkers. Highland cattle were favored but unfortunately were not available. Some provisions for cattle grazing had been provided in the Management Agreement from the start of the project, but cattle were eventually brought to the site as an alternative to sheep grazing, when four 8-month old heifers of modern breeding were introduced in 2012-2013. Survey in 2014 found *S. stigmaticus* in the center of the field, away from the coastal remnant colonies, but not across large areas of it, due to the grazing intensity remaining too low (Selman 2014). Subsequently with the end of the Management Agreement in 2012 there has been only very limited consented grazing by sheep and ponies

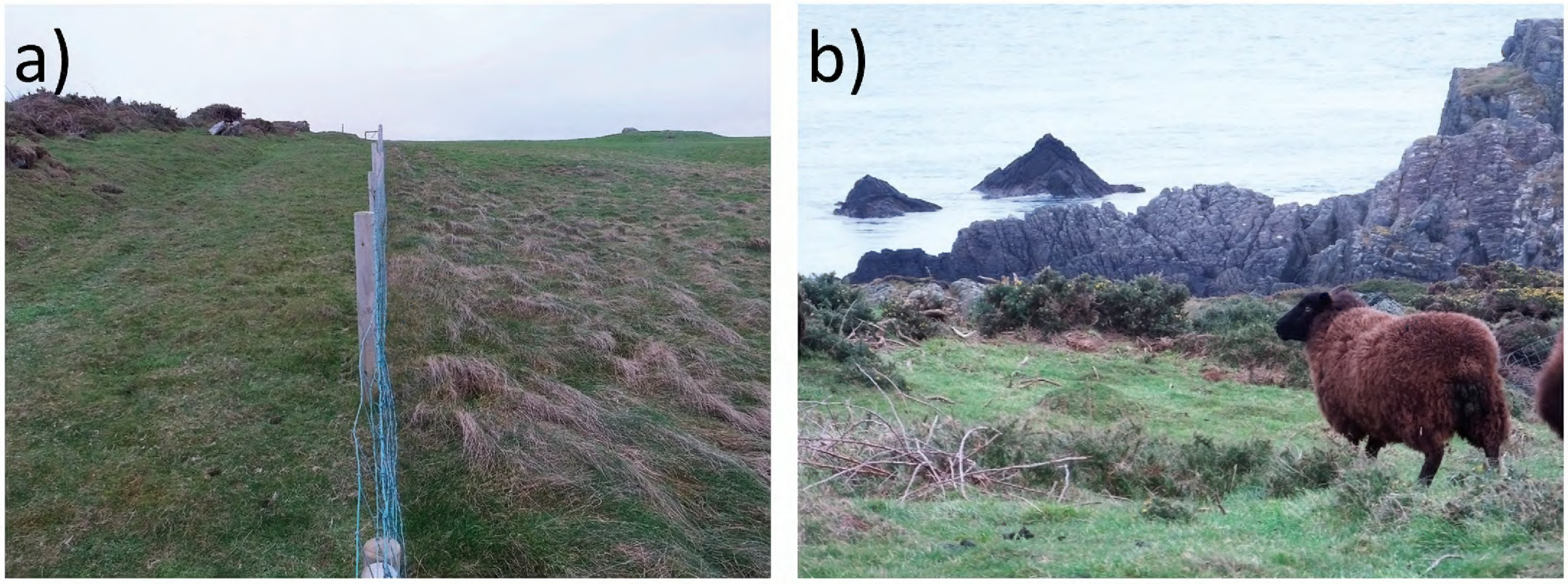

Fig. 3. The impact of targeted grazing in January 2017 after clearance of gorse two years earlier, **A.** vegetation either side of fencing; **B.** hardy Welsh Mountain-Texel cross sheep grazing on-site.

at levels insufficient to maintain habitat suitable for *S. stigmaticus*. A new Management Agreement is being negotiated with the landowner, who wishes to introduce Highland cattle.

As with discussions around the access issue, progress with grazing has been hindered by long lines of communication between the officers of DEFA, the landowners, their agents, the tenant, and the tenant's grazier. This produced complex and slow negotiations around issues arising. Moreover, no one lives permanently on the peninsula who can address issues as they occur.

Overall, the Management Agreement failed to deliver the desired outcomes at a large scale due to the prescription not being delivered fully, but did demonstrate that improvement in habitat suitability and population size of *S. stigmaticus* are achievable if grazing is managed effectively.

Small scale mitigation works and targeted gorse clearance.—In 2015, the relocation of a golf course fairway was accompanied by ecological mitigation work agreed with DEFA as part of planning consent. An area of 2.5 ha was targeted for the clearance of gorse from around rocky outcrops known to have supported a single *S. stigmaticus* on a tiny rabbit-grazed patch in 2002. After gorse was removed the area was fenced off and grazed with barren ewes at a stocking rate of approximately 13 ewes per ha for several months in spring, and then again in the autumn. These were then replaced with similar numbers of yearlings (born that year and just weaned) which have grazed each year from September/October to May/early June in both 2016 and 2017. By the summer of 2017, the site was looking ideal for *S. stigmaticus* with short grass, outcropping rocks and a south-facing slope at the head of a gulley leading down to the shore (Fig. 3). A small number of *S. stigmaticus* were found in July 2017, within grassland and heath on a short headland in an area that was occupied by *S. stigmaticus* in 1990, but not in the early 2000s, demonstrating the potential for successful habitat restoration through targeted gorse clearance and grazing when the opportunity arises (Selman 2017).

Management within the golf course

Preliminary observations suggest that on the course, *S. stigmaticus* is restricted to grassland similar in structure to its habitat elsewhere on the peninsula. In the summer, fairways and the semi-roughs (between fairways and roughs) are cut weekly to about 10 mm and 16 mm respectively. *S. stigmaticus* is absent from fairways, but occurs in some areas of semi-rough. It is unclear whether *S. stigmaticus* survives mowing or if semi-rough represents a sink-habitat for grasshoppers dispersing from adjacent rough where scattered colonies occur. In the roughs, *S. stigmaticus* is found on mown areas, and on unmown but dry free-draining mounds of semi-natural grass (Fig. 1F). Cutting of roughs occurs once a year in winter with a flail mower, and some areas are also slot-tined to improve drainage. Adjacent unmown roughs, away from mounds, have damper, thicker grassland and these areas always lack *S. stigmaticus*.

Mowing in summer can be highly damaging for nymphs and adult grasshoppers (Gardiner and Hill 2006, Humbert et al. 2010), but our observations suggest that an autumn or winter cut, while the grasshopper is in the egg stage, can help maintain suitable habitat (Selman 2009, 2014). Research on the effects of mowing would be useful. The effects on grasshopper eggs of chemical, biological and physical methods to control leatherjackets (the subterranean larvae of Tipulid flies) (Christians et al. 2016) also warrant investigation. Areas of rough, some supporting *S. stigmaticus*, were previously treated with the insecticide chlorpyrifos during winter with unknown consequences for grasshopper eggs (Selman 2012).

Overview of grazing impacts and future prospects

Over 25 years of observations at Langness suggest that re-introducing grazing will allow *S. stigmaticus* to spread beyond its current strong-holds around rocky outcrops where grass is naturally short and sparse as a result of thin soils, salt spray and rabbit grazing. Overall, these observations accord with those from elsewhere in Europe. In the Netherlands, the population density of *S. stigmaticus* was found to increase in response to grazing of tall grasslands by cattle (van Wingerden et al. 1991a), and Jauregui et al. (2008) found a similar result using goats to graze a dwarf-shrub heath in north-west Spain. The need to carefully monitor grazing has been demonstrated at some continental sites, however, because heavy grazing in nutrient poor dry grasslands with very short turf can suppress densities of *S. stigmaticus* (van Wingerden and Dimmers 1993).

Since 2002 there have been some beneficial changes in management for *S. stigmaticus* at Langness, and an improved local recognition of the areas of importance for this species and its requirements, but there have also been some challenges and the beneficial effects have mostly been localized. The major management problems encountered have been socio-economic, resulting from difficulties in sourcing suitable livestock and the unintended consequences of fencing and recreational activity, rather than shortfalls in ecological knowledge. Grazing remains the preferred solution for achieving suitable habitat, but mowing in winter may need greater consideration because of continued problems in integrating livestock with public access.

Conclusions

Conservation action for *S. stigmaticus* has, in summary, now included species protection (1990), site protection (2000), distribution mapping (1964 onwards), management agreements for fenced grazing funded through agri-environment payments (2001–2012), consented grazing (discussion ongoing post-2012), and gorse clearance with fenced grazing facilitated as mitigation for development (2014 onwards). This has achieved a level of confidence that key areas can be retained in future and has had success in improving *S. stigmaticus* habitat in some areas, but not on the scale hoped for.

Key lessons are to: a) minimize restrictions on grazing, stating what habitat structure we need rather than prescriptive management techniques, as we have not experienced overgrazing but have frequently encountered undergrazing, so a flexible approach to grazing opportunities may be necessary; b) attempt the simplest agreement and communication route between the paying organization and the grazier; c) consider setting up a public forum for management discussions, if the landowners are happy to do this, with the benefits of encouraging public buy-in to a management strategy and the potential for minimizing problems arising from recreational access with dogs; d) consider winter cutting techniques outside of the golf course, that avoid significant risks to grasshoppers but which might allow management in areas where grazing is not currently possible; and e) continue to explore opportunities for small-scale targeted scrub control, particularly around rock outcrops, followed by grazing, where practicable, though rabbits can also help control scrub following cutting.

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References

Behrens M, Fartmann T (2004) Die Heusschreckengemeinschaften isolierter Schieferkuppen der Medebacher Bucht (Sudwestfalen/Nordhessen). Tuexenia 24: 303–327.

Bellman H (1988) A field guide to the grasshoppers and crickets of Britain and northern Europe. Collins, London.

Benton T (2012) Grasshoppers and crickets. New Naturalist No. 120. Harper Collins, London.

Burton JF (1965) Notes on the Orthoptera of the Isle of Man with special reference to *Stenobothrus stigmaticus* (Rambur) (Acrididae). Entomologist's Monthly Magazine 100: 193–197.

Cannan JDQ, Cregeen GD, Malarkey WM (2008) Report of the Delegation on Langness. Tynwald Document PP134/08. Tynwald Parliamentary Library, Isle of Man. http://www.tynwald.org.im/business/pp/Reports/2008-PP-0134.pdf [Last retrieved 6 December 2017]

Cherrill AJ (1990) A survey of the grasshoppers of the Isle of Man, with particular reference to the distribution, biology and conservation of *Stenobothrus stigmaticus* (Rambur) on Langness Peninsula. Manx Museum and National Trust, Isle of Man.

Cherrill AJ (1994) The current status of the lesser mottled grasshopper *Stenobothrus stigmaticus* (Rambur) on the Isle of Man. British Journal of Entomology and Natural History 7: 53–57.

Cherrill AJ, Selman RG (2002, 2006) Surveys of the grasshoppers of Langness, Sandwick and Derbyhaven Area of Special Scientific Interest; with particular reference to the lesser mottled grasshopper *Stenobothrus stigmaticus* (Rambur). DAFF, Isle of Man.

Christians N, Patton A, Law Q (2016) Fundamentals of turfgrass management. J. Wiley and Sons, New Jersey.

Detzel P (1998) Die Heuschreken Baden-Wurttembergs. Verlag Eugen Ulmer, Stuttgart.

Elligsen H, Plachter H, Satzger R (2010) Grazing-induced 'disturbed areas' in vegetation creating microhabitats for butterflies and grasshoppers on an Ukranian pasture. In: Plachter H, Hampicke U (Eds) Large-scale livestock grazing: a management tool for nature conservation. Springer-Verlag, Berlin, 111–117. https://doi.org/10.1007/978-3-540-68667-5_5

Gardiner T, Hill J (2006) Mortality of Orthoptera caused by mechanical mowing of grassland. British Journal of Entomology and Natural History 19: 38–40.

Harz K (1975) The Orthoptera of Europe II. Series Ent. 11, W. Junk, The Hague. https://doi.org/10.1007/978-94-010-1947-7

Hoffmans K, Barenburg B, Backeljau T (1989) The non-tetrigid Saltatoria (Insecta) of the Belgian chalk grasslands. Verhandelingen van het Symposium, Invertebraten van Belgie, 257–263.

Holst K (1986) The Saltatoria of northern Europe. Fauna Entomologica Scandinavica 12. E.J. Brill/Scandinavian Science Press, Copenhagen.

Humbert JY, Ghazoul J, Richner N, Walter T (2010) Hay harvesting causes high orthopteran mortality. Agriculture, Ecosystems and Environment 139: 522–527. https://doi.org/10.1016/j.agee.2010.09.012

Isern-Vallverdu J, Cuartas P, Pedrocchi C (1995) Diet selection of three grasshopper species (Orthoptera, Acrididae) in Spanish Pyrenees. Journal of Applied Entomology 119: 345–349. https://doi.org/10.1111/j.1439-0418.1995.tb01298.x

Jauregui BM, Rosa-Garcia R, Garcia U, WallisDeVries MF, Osoro K, Celaya R (2008) Effects of stocking density and breed of goats on vegetation and grasshopper occurrence in heathlands. Agriculture, Ecosystems and Environment 123: 219–224. https://doi.org/10.1016/j.agee.2007.06.004

Johannesen J, Samietz J, Wallaschek M, Seitz A, Veitch M (1999) Patch connectivity and genetic variation in two congeneric grasshopper species with different habitat preferences. Journal of Insect Conservation 3: 201–209. https://doi.org/10.1023/A:1009695612760

Länder S (2000) Mikrohabitatbindung von *Stenobothrus stigmaticus* (Rambour, 1839) (Orthoptera: Acrididae) auf der Rekumer Geest. Diploma thesis. Institute of Ecology and Evolution, Department of Biology, University of Bremen.

NLWKN (2011) Invertebrates with priority for conservation and development measures - Small Heath Grasshopper *Stenobothrus stigmaticus*. Lower Saxony State Enterprise for Water Management, Coastal and Nature Conservation, Hannover. http://www.nlwkn.niedersachsen.de/download/50191 [Last retrieved 15 July 2017]

Radcliffe FJ, Garrad L (1990) Langness. Field Guide No. 1. Natural History and Antiquarian Society, Isle of Man.

Ragge DR (1963) First record of the grasshopper *Stenobothrus stigmaticus* (Rambur) (Acrididae) in the British Isles, with other new distribution records and notes on the origin of the British Orthoptera. The Entomologist 96: 211–217.

Ragge DR (1965) Grasshoppers, crickets and cockroaches of the British Isles. Warne, London.

RPS Clouston (1990) Langness Peninsula. Ecological evidence given on behalf of the Palace Group. RPS Clouston, Oxon.

Selman RG (2009) Lesser mottled grasshopper surveys 2009, Langness Peninsula. DAFF, Isle of Man Government.

Selman RG (2012, 2014) Lesser mottled grasshopper surveys 2012/2014, Langness Peninsula. DEFA, Isle of Man Government.

Selman RG (2017) Lesser Mottled Grasshopper Survey 2017, with notes on golf course management. DEFA, Isle of Man Government.

van Wingerden WKRE, Dimmers WJ (1993) Effects of rabbit and cattle grazing on grasshoppers (Orthoptera: Acrididae) of river dunes. Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society 4: 127–136.

van Wingerden WKRE, Heeren N (1998) Does cattle grazing facilitate *Stenobothrus stigmaticus* (Rambur) (Orthoptera: Acrididae) by improving quality and accessibility of *Deschampsia flexuosa*? Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society 9: 77–85.

van Wingerden WKRE, van Kreveld AR, Bongers W (1992) Analysis of species composition and abundance of grasshoppers (Orthoptera, Acrididae) in natural and fertilised grasslands. Journal of Applied Entomology 113: 138–152. https://doi.org/10.1111/j.1439-0418.1992.tb00647.x

van Wingerden WKRE, Musters JCM, Kleukers RMJC, Bongers W, van Biezen JB (1991a) The influence of cattle grazing intensity on grasshopper abundance (Orthoptera: Acrididae). Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society 2: 28–34.

van Wingerden WKRE, Musters JCM, Maaskamp FIM (1991b) The influence of temperature on the duration of egg development in West European grasshoppers (Orthoptera: Acrididae). Oecologia 87: 417–423. https://doi.org/10.1007/BF00634600

Werkgroep Saltabel (2017) *Stenobothrus stigmaticus*. Benelux orthoptera working group. http://www.saltabel.org/nl/soorten/Acrididae/Stenobothrus_stigmaticus [Last retrieved 15 July 2017]